

Name _____

Activity: A Moving Model of the Beginning of the Universe
For 9th Grade Physical Science

Introduction: Astronomers have found evidence that the universe began with what is called "the Big Bang." At first the universe was a sea of quarks. The quarks combined to form protons and neutrons. There was one neutron for every seven protons. This activity shows how the nuclei of isotopes of hydrogen and helium were made. Students move and display cards that show how particles combine. Students must know what they should do, cooperate, and listen to create a good model. (This is a lot like a square dance or folk dance in which everyone has a part.)

Isotopes that can form: **Hydrogen: Deuterium** (one proton and one neutron in a nucleus) and **Tritium** (one proton and two neutrons in a nucleus). **Helium: Helium 3** (two protons and one neutron in a nucleus) and Helium-4 (two protons and two neutrons in a nucleus). **Beryllium: Beryllium 7** (four protons and three neutrons). The Beryllium changes into lithium quickly because it is unstable. **Lithium: Lithium 7** (three protons and four neutrons). If you form deuterium or Helium 3 you can meet with others to form even heavier nuclei.

If a proton gives off a positive charge (called a positron), it changes into a neutron. Why? _____

At first there were only protons and neutrons. Discussion:

How can a Deuterium nucleus form from a proton and a neutron? Draw 2 possibilities.

How can a Helium 3 nucleus form ?

What are four different ways that a Helium 4 nucleus can form?

1. _____
2. _____
3. _____
4. _____

Beryllium 7 is formed by a Helium 3 and a Helium 4 joining together. If a Beryllium 7 group throws out a positron, one proton changes into a neutron and a Lithium 7 nucleus is formed.

Why is the atomic mass of the Lithium 7 nucleus the same as the atomic mass of the Beryllium 7 atom? _____

Materials needed: A set of cards for each student. One card has **PROTON** printed on one side and **NEUTRON** printed on the other side. Others are labeled **DEUTERIUM**, **HELIUM 3**, and **HELIUM 4**. Two signs for the class: **10 billion K** and **1 billion K**. Ping pong balls to represent positrons.

Important Ideas:

1. Because it was so hot in the early universe, everything moved very fast. (This is the kinetic theory.) It is not possible to model this well because we will need to take time to decide what new nuclei to form or not to form.
2. Only the nuclei of simple atoms formed. It was too hot for electrons to stay around nuclei. So there are no electrons in shells or electron clouds.
3. Each student represents an atomic mass unit of 1 and is either a proton or a neutron. You will be assigned to be a neutron or a proton. Most are protons
4. Not until 100 seconds and cooling to 1 billion K do protons and neutrons stick together.
5. Students combine to make heavier nuclei and elements heavier than normal hydrogen. Students will decide if they wish to stick and form new nuclei. In nature the speeds and angles at which particles bumped determined if the particles would stick.
6. It is important to make the charges correct. As above, if two protons stick to form deuterium, one of the protons must change to a neutron. To do this the proton emits a positron.
7. Everyone must be observant, serious, and quiet so that the model can work and problems can be solved. Hold your sign up high so other groups know what is possible if they meet you. Look at the other signs and listen for cues. Hide signs that are no longer correct and hold up signs that are correct.
8. When students who are alone or in groups meet others, bump very gently.
9. Know what combinations are possible. Do not argue with other students about sticking or not. Do not talk. Simply drop hands if you do not wish to join and do not force others to join with you. Do not seek out a particular model to meet or stick to--You should meet by chance.
10. When you gently bump, you may break apart into the original particles instead of making a more complex group. Don't forget this. Do it sometimes.
11. At 1000 seconds more complex particles can join than at 100 seconds, since the particles are cooler and moving less rapidly.
12. When "End" is called by the teacher, everyone should freeze in place--no moving and no talking to each other. We will see what particles we have formed and decide how to adjust the model to show actually what was left after about 1000 seconds.
13. In the universe there were many, many, many, many more protons and neutrons than we have people in the class, so what we do happened on a much larger scale.
14. Elements heavier than the ones formed in this activity (the rest of the periodic table) were formed mostly inside aging stars. Stars began forming about 400,000 years after the big bang and the galaxies possibly formed about 1 billion years after the big bang.

Procedure (The "Script"): Sketch what you think each will be like. Use stick figures for people in your drawings.

1. Students arrange in a dense group in the center of the room. In the beginning it is dark.
2. The teacher will call "Big Bang!" Room lights are turned on.
3. On this cue, the teacher will hold up a large sign of "10 billion K."
4. Each student represents either a proton or a neutron that formed from 3 quarks. Most students will hold up the **PROTON** sign. Three people will hold up the **NEUTRON** sign.
5. Students start moving out from the center, although in a zigzag direction so they will encounter other students..
6. Some students should encounter (safely bump) other students. But you must move away; you cannot stick together at this high temperature.
7. The teacher will call "100 seconds." The teacher exchanges the first temperature sign for one showing "1 Billion K."

8. Now when two student protons meet, they decide if they will bounce away or stick together. Either is possible. Hold hands if you join. Two protons stuck together become a **DEUTERIUM** nucleus. In the nucleus there is 1 proton and 1 neutron.. To get a neutron from a proton, the proton must throw off a positron. If you form a deuterium nucleus take a ping pong ball (a positron) and throw it clear of all students. One student in the **DEUTERIUM** group holds up a **DEUTERIUM** sign.

If a proton meets a neutron, the two students decide if they will bounce away or stick to make **DEUTERIUM**. No positrons or other particles are released.

9. Students continue to bend back and forth. In general, they move away from the center.

10. If a **DEUTERIUM** meets a neutron, students may bounce away or stick. If they stick, **HYDROGEN-3** (also called **TRITIUM**) forms. These students hold hands. One now holds up a **HYDROGEN-3** sign. Hide the other signs.

11. The teacher will call "1000 seconds." Now some other combinations are possible. If a **DEUTERIUM** meets a proton and decides to stick, join hands and hold up a **HELIUM 3** sign. Hide the other signs

12. If two **DEUTERIUM** couples meet and stick, join hands and hold up a **HELIUM 4** sign. Hide the other signs.

13. From our discussion at the start, all of the following are also possible ways to form **HELIUM 4** when student nuclei groups bump one another. When you bump you may form **HELIUM 4** in one of these ways. Hold up the **HELIUM 4** sign and hide other signs. Released protons and neutrons now move alone and hold up a proton or neutron sign. Make sure you know which. The protons and neutrons can take part in future changes.

Helium 3 + Deuterium forms Helium 4 + a proton

Helium 3 + Deuterium forms Helium 4 + a neutron + a positron

Helium 3 + a neutron forms Helium 4

Helium 3 + Helium 3 forms Helium 4 + 2 protons (2 people leave the group)

14. A very little Lithium (element with atomic number of 3 and atomic mass of 7) formed in the early universe. We will have one Lithium nucleus to represent this if students have formed at least one **HELIUM 3** nucleus and one **HELIUM 4** nucleus. The teacher will direct a Helium 3 and a Helium 4 to stick together. The group holds up a **BERYLLIUM 7** sign. Beryllium 7 has four protons and four neutrons. To form Lithium 7, which has three protons and four neutrons, one proton must be changed to a neutron. So one person in the **BERYLLIUM 7** group throws a ping pong ball (a positron) clear students. The group holds up a **LITHIUM 7** sign. (Another way to get **LITHIUM 7** is for a free electron to join a proton in the Beryllium 7 and turn it into a neutron.) Any Beryllium that formed in the early universe, changed into lithium like this, so Beryllium now present formed later in stars.

15. The teacher will call “End.” The universe has cooled and expanded so the reactions cannot continue like this. The student with the temperature card puts it down.

16. Students freeze in position and hold up the signs. Discuss how this is different from the percentages of atoms that really formed. The teacher will direct some “nuclei” to change to represent the percentages of the nuclei that really formed. (Sketch what you think the end may look like.)

With _____ students, the following nuclei formed from the original 3 neutrons and _____ protons:

Number of Deuterium (Hydrogen 2) nuclei: _____

Number of Tritium (Hydrogen 3) nuclei: _____

Number of Helium 3 nuclei: _____

Number of Helium 4 nuclei: _____

Number of Lithium 7 nuclei: _____

17. If there is time repeat the activity. If repeated, do you think that the class will form the same number of each nucleus that it did the first time? _____

Why do you think this? _____

Questions:

1. How are the numbers of particles and nuclei we formed different from those formed in the early universe? _____

2. If we had started the model at an earlier fraction of a second in the age of the universe when there were quarks, how could we have modeled the formation of protons and neutrons? _____

3. What is incorrect about “freezing” the motions at the end of the activity?

4. Why do you think that the Beryllium 7 nucleus is so unstable that it changes into a Lithium 7 nucleus, and why is the Lithium 7 nucleus more stable?

5. How many minutes in the early universe does this activity represent?

